

**A Proposal from:**

**InterTronic Solutions and Eltac Ltd.**

**For:**

**A prototype set of stages for a Class A, 20 MHz to  
1000 MHz flat phase, stable gain amplifier for use  
with particle accelerator feedback systems**

**To: SLAC**

**Quotation ref number 14028**

**Commercial in confidence**

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**Prepared by    S Thompson  
                      P Shield**

**Dated 11<sup>th</sup> April 2014**

## **Proposal to develop and supply a prototype 4 output stage ultra-broadband feedback power amplifier demonstration unit**

### **1. Introduction**

This document contains extensive details of our heritage and experience designing and building amplifiers for similar applications.

It also contains a proposal to demonstrate the performance of a fully representative set of stages, including the power splitters and combiners and 4 combined output stages for a 20-1000 MHz linear, flat phase power amplifier to be used as a feedback amplifier for enhanced control of instabilities in a particle accelerator application.

This application is special in that most “off the shelf” power amplifiers that cover this band just do not have the gain flatness, pulse response or flat stable phase characteristics needed over this bandwidth. We understand the reasons behind this lack of performance.

What we propose here is to design, produce, test and deliver a prototype PCB based unit with enough stages fully combined (4 output stages producing around 20-25 watts of P<sub>1</sub> dB output power) to show that we could then make full power amplifier systems, taking all the risk out the next steps.

The target specifications for a full amplifier system would be: >60dB of linear gain, 20-1000 MHz instantaneous bandwidth, 250-300watts P<sub>1</sub>dB, pure class A linear gain performance, only 10-20 Deg of phase deviation across the whole band, and fully acceptable pulse performance

We believe that we are the only company who has already demonstrated the performance required here as a few years ago we designed and built 3 complete 300-400 watt systems for a similar application at the Oak Ridge SNS. These systems covered 5-300 MHz and are still in full operation today. They had to do exactly what is required here in terms of gain, phase, ultra wide bandwidth, and pulse response.

## **2. Heritage**

**Eltac Ltd**, our principal subcontractor, is owned and managed by the Company's founder, Steve Thompson. Steve has an honours degree in Electronic Engineering from Southampton University UK, (1979). Prior to founding Eltac in 1990, Steve worked as a design engineer with Marconi (Radar and Military Communications Divisions), Plessey Military Communications and as an applications specialist with Acrian Inc. (a San Jose CA company who manufactured RF power transistors).

Eltac was established to be a flexible specialist RF engineering resource, reacting to customer's requirements rather than selling a catalogue of products and, 17 years on, continues in this manner. Throughout that time work has flowed from recommendations, reputation and personal introduction.

Eltac has an extensive inventory of RF test equipment and operates from modern laboratory and workshop facilities in Aldermaston, England. The company is entirely self financing, and the building and all equipment are wholly owned.

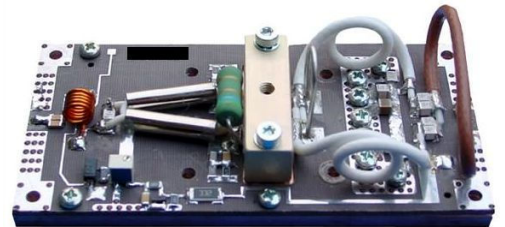
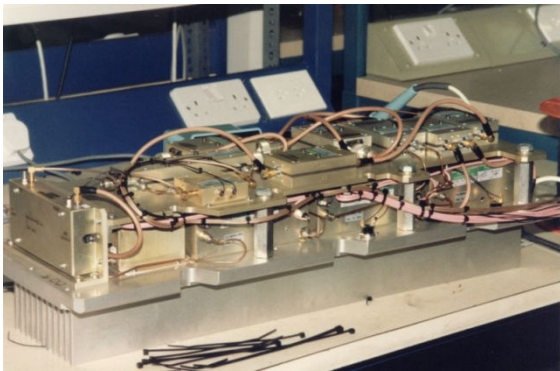
Most work falls in the frequency range 10kHz-3GHz, and can involve applications from low noise receivers to kW level amplifiers.

Customers and end users have included US DoE (Oak Ridge National Lab), UK Defence Research Agency, Racal Avionics, BAE Systems, JET Fusion Reactor, CHESS, EF Johnson, Ericsson, Vodafone, Motorola Mobile Radio, Decibel Mobilcom, Siemens Communications Systems, Isomet..

### **Some past Eltac projects that can be mentioned include:**

- Two 20 kW pulsed amplifiers at 204 MHz for CHESS (see page5)
- 100W mobile radio base station designed and prepared for customer production. Approx. 2500 units in service.
- Ultra linear UHF amplifiers to carry trunked radio signals underground in the Tyne & Wear Metro (a subway system in Newcastle, England). 26 amplifiers were installed in 1991/2, each operating at 150W dissipation '24/7' since then. They have accumulated well over 3million operating hours, and earlier this year we had the first and only field failure.
- Ultra linear bi-directional, high gain, amplifiers for extending 800MHz trunked radio communications into blast proof bunkers at oil refineries. Andrews, Decibel and others all carried such products in their catalogues, but could not deliver in practice. Eltac designed and delivered units in a matter of weeks.

- Compact 50 and 100W 500-1000MHz amplifiers for jamming applications. These products have been in continuous production since 1990.
- 1.5kW sources at 13.56MHz and 27.12MHz for industrial plasma generators and laser excitation.
- 5-300 MHz, 400 watt ultra flat phase power amplifier for use in a large LINAC broadband feedback system.
- Single channel filtered on-frequency repeaters with controlled delay and group delay for carrying paging signals into 'dead' areas.



**InterTronic Solutions Inc.** is a CGRP registered (a Canadian defense classification) manufacturer, design and sales company based upon over thirty years of experience in the Microwave, Aerospace and Electronic Engineering fields. We have particular expertise in solving customers microwave and RF problems and requirements. We are the appointed representatives for several established ISO 9000 registered manufacturers whose products have unique advantages. We are set up in SAMS, the CCR, and numerous other US procurement systems.

InterTronic Solutions specializes in power amplifier systems and complex antenna systems.

We are noted for our project management skills and excellent customer service. We design and manufacture our own range of precision antenna system that span up to 12m apertures for major radio astronomy, NASA and other defense applications and we are involved with several major NASA programs.

We are experienced with the following applications and markets: Defense and radar systems, particle accelerators and physics research, deep space communications, radio astronomy and VLBI and NASA radar applications.

Examples of some of our other amplifier products:

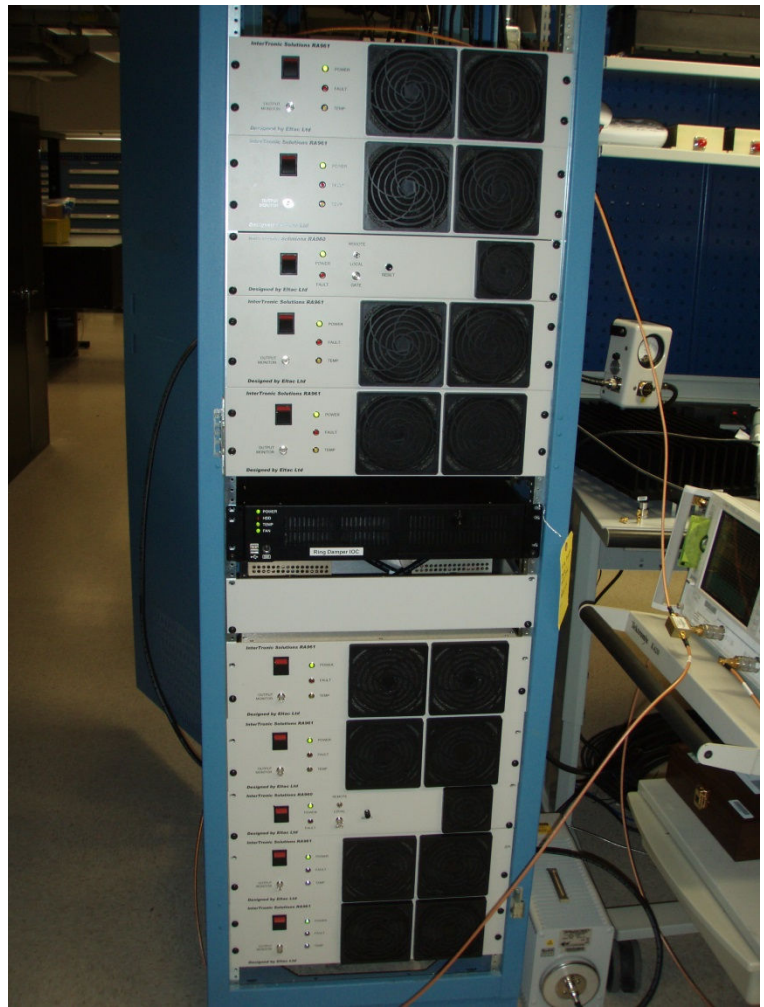




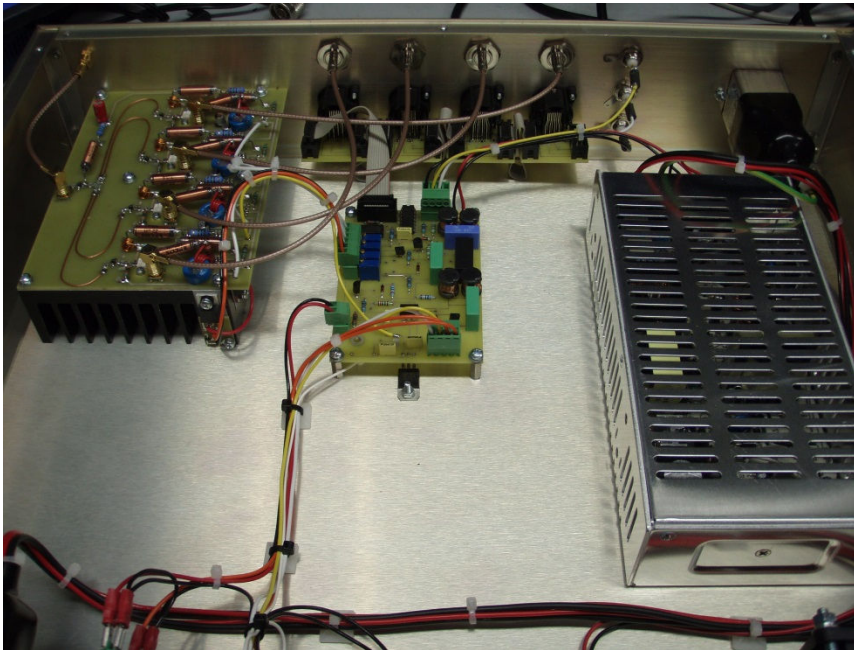
### **3. Proposed amplifier system description**

Whilst this is a proposal for just a prototype of the main stages of the overall amplifier system the prototype amplifier proposed is based on work from three very similar but lower frequency units we built for Oak Ridge SNS, these are shown below. A reference can be provided upon request.

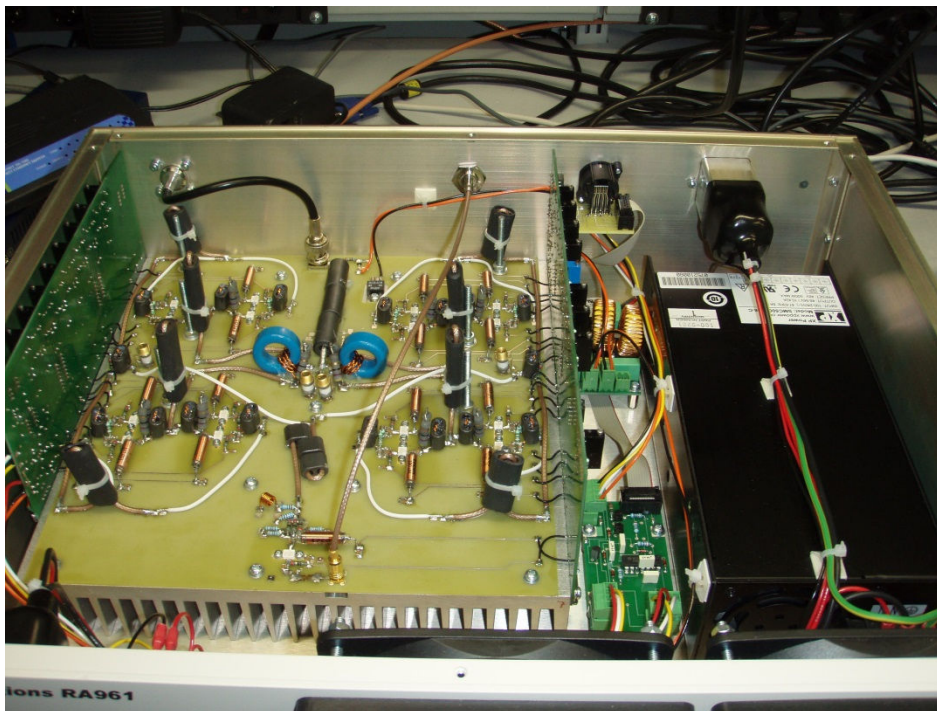
#### **Similar 300-400W, 5-300 MHz power amplifiers**



**Internal view of our 5-300 MHz RA960 driver unit**



**Internal view of our 5-300 MHz RA961 100 watt unit using 16 output stages**





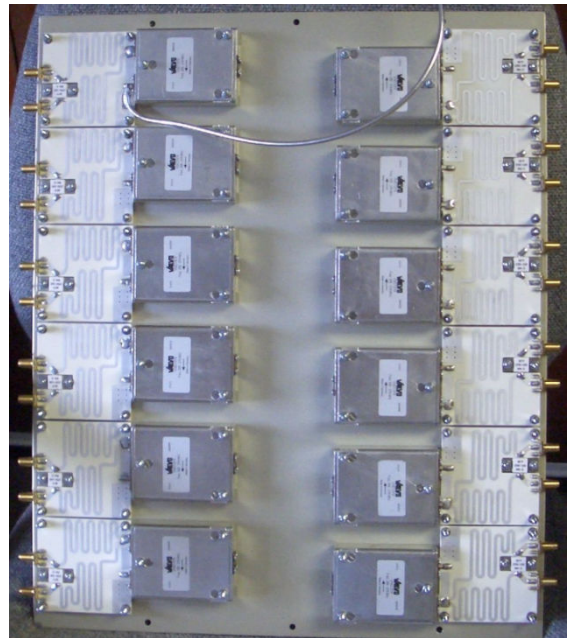
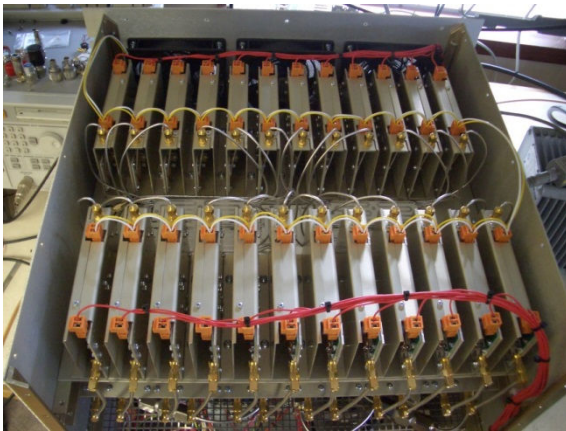
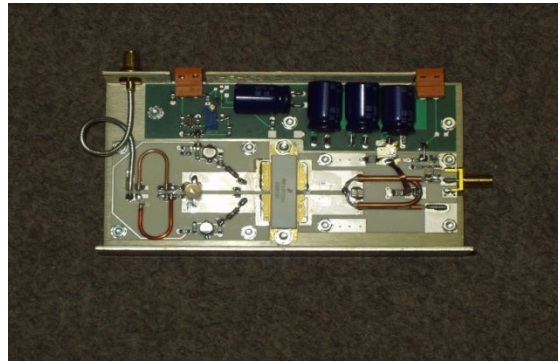
**Examples internal pictures of some other 20 Kwatt narrow band amplifiers we built for another physics application (showing that we also design and make narrow band high powered pulsed and CW amplifiers)**

**Internal photos of our 20 kW amplifiers**

**24, 1 kW stages**



**Single 1 kW stage**





### Detailed description of our previous 5-300 MHz broadband design

The RA959 system is a broad band linear amplifier covering 5-300MHz at >300W output, with excellent phase linearity and gain flatness. The amplifier is ideally suited to a wide range of applications including uses where linear feedback systems are incorporated.

The system comprises six 19" rack mounting units with interconnecting cables:

- 1 x RA960 Driver Amplifier and Splitter
- 4 x RA961 100W Amplifiers
- 1 x D8106 Output Power Combiner

### Functional Description

The RA959 Amplifier System consists of a Driver Amplifier and 4 way splitter feeding four separate Amplifiers, each of nominally 100W output, which outputs are combined to provide the final output from the system.

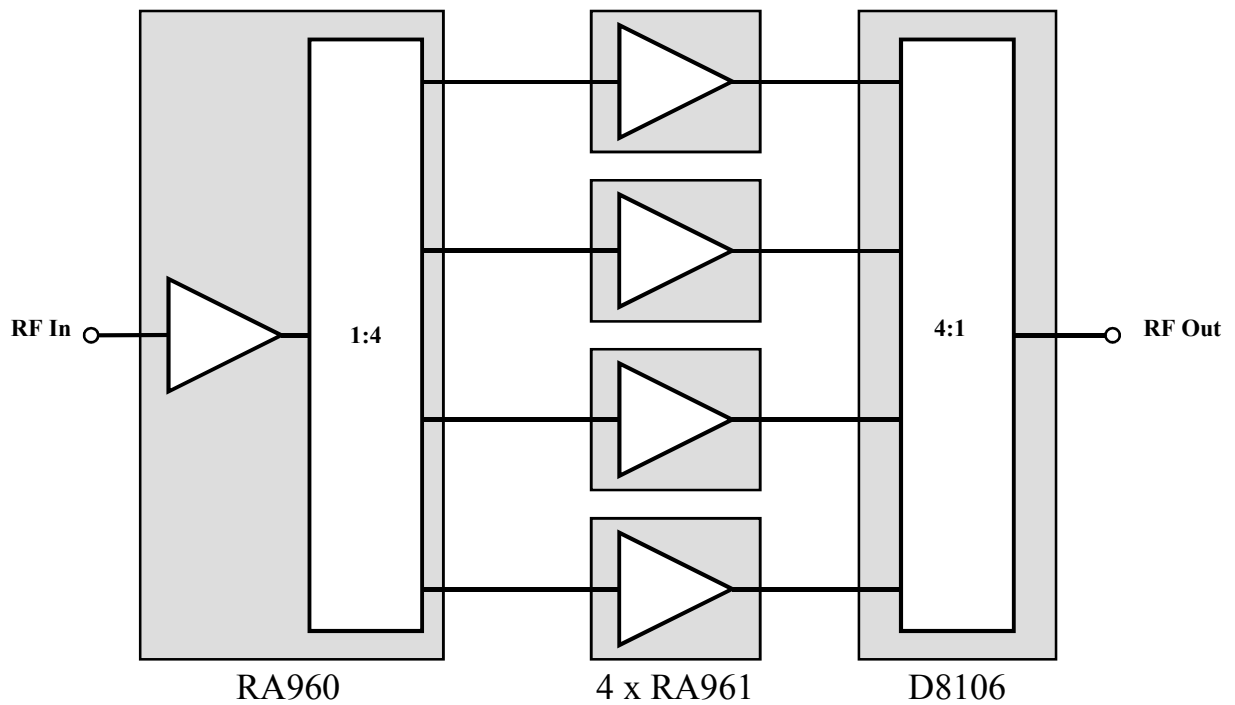


Figure 1: RA959 Amplifier Configuration

### RA960 Drive Amplifier

The drive amplifier unit provides the initial stages of gain and splits the RF path into four parallel channels, each of which has an output power of nominally 250mW.

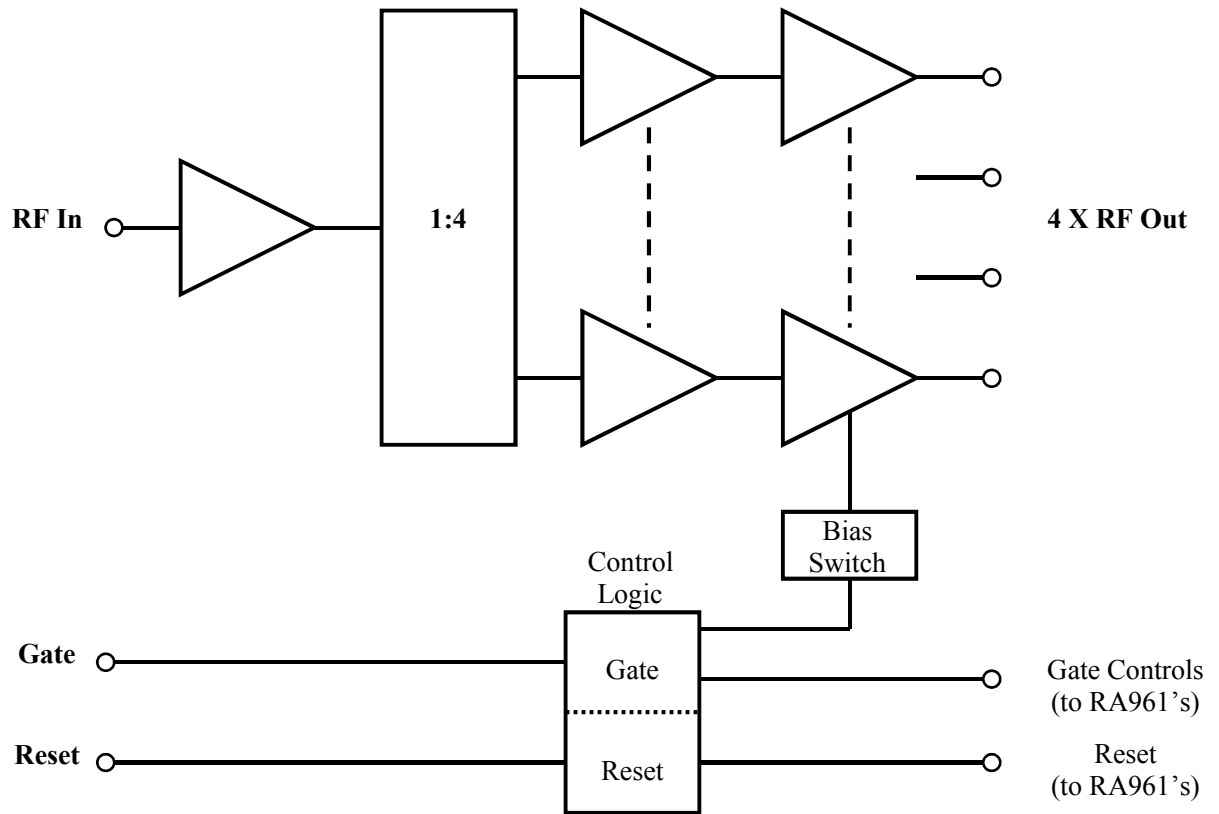


Figure 2: Drive Amplifier Configuration

## RA961 100 Watt Amplifier

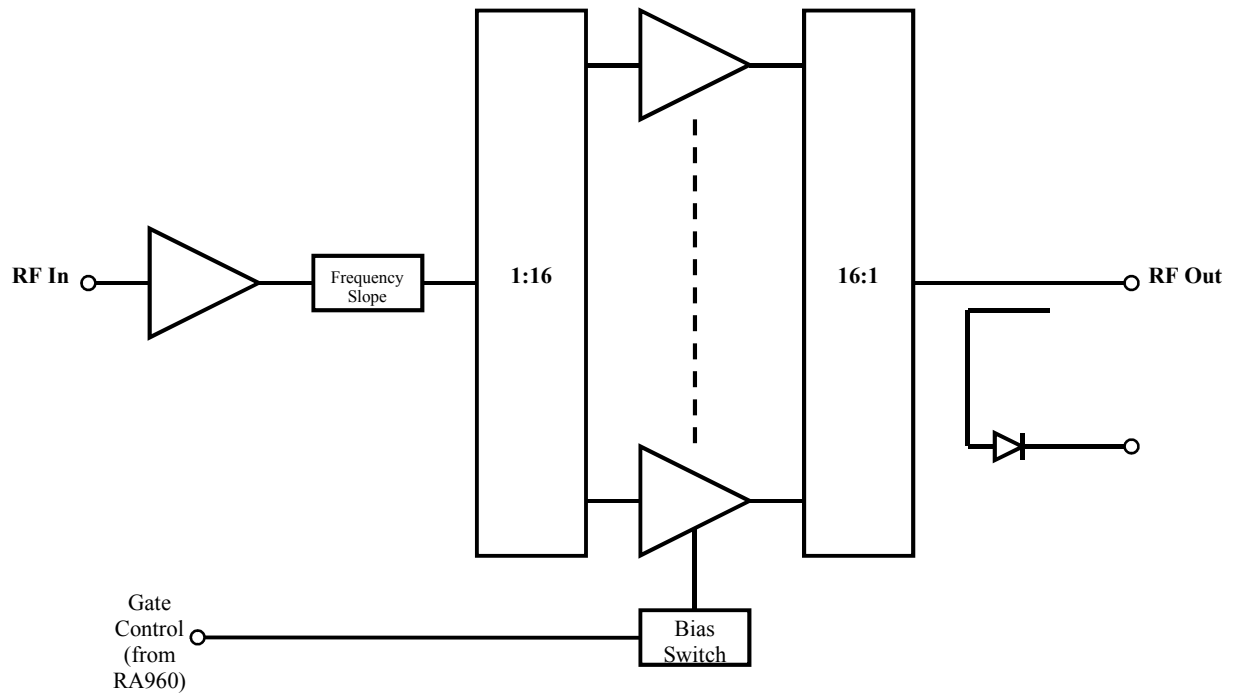


Figure 3: 100 Watt Amplifier Configuration

## Performance

The amplifier is designed to have extremely flat amplitude and phase responses across the 5–300 MHz operating bandwidth. Typical network analyzer measurements of the amplifier system performance are shown in Figure 4 below.

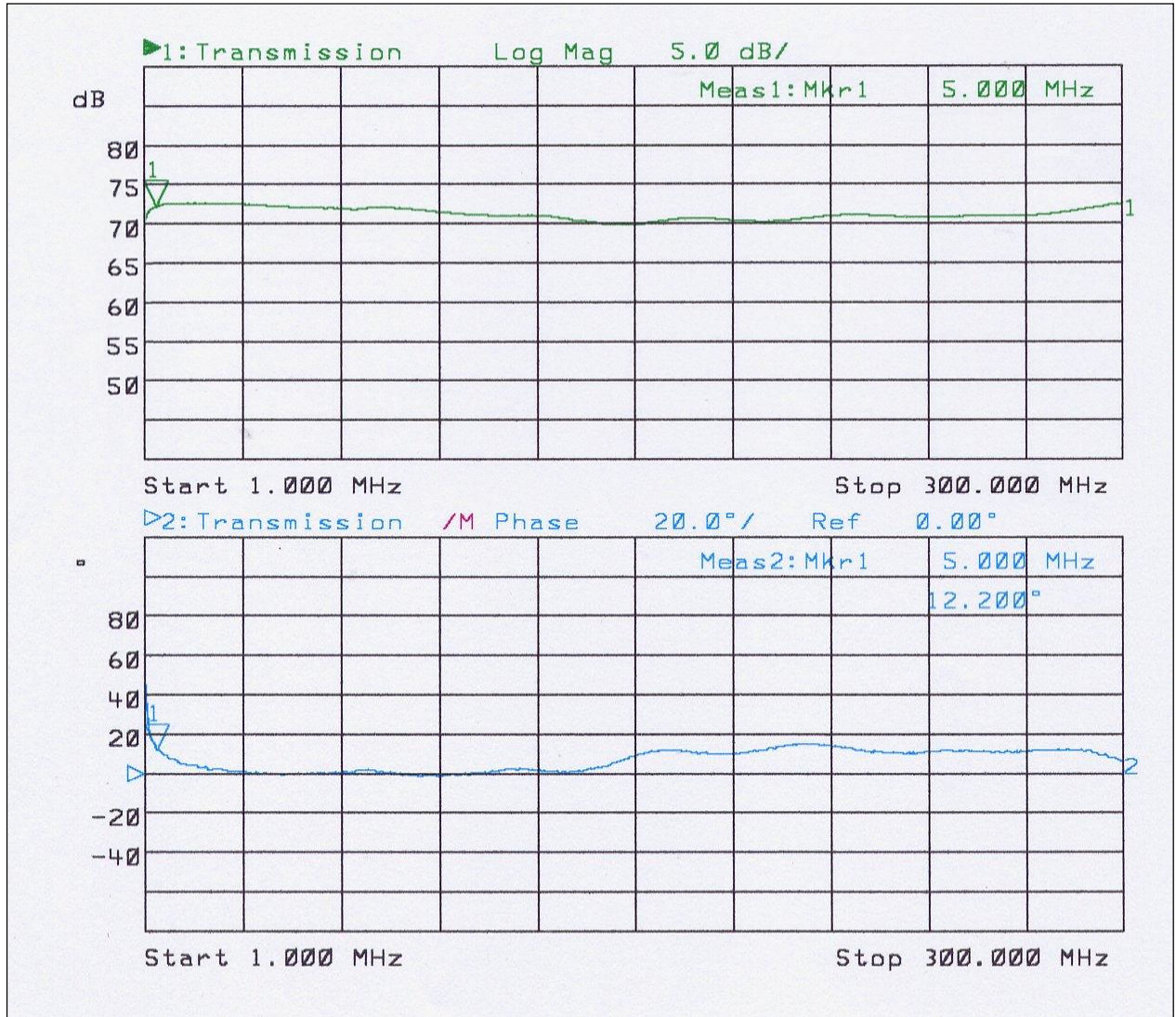


Figure 4 Typical Amplifier System Performance



## RA960/961 Specifications

Frequency range	5-300MHz
Input port	
Impedance	50 Ohm nominal
Connector	SMA (f)
VSWR	1.6:1 max
Input Signal	
Type	Pulse
Duration	1ms max
Duty cycle	15% max
Also capable of full power CW operation	
Noise Figure	< 6dB
Gain	70dB nominal
Gain flatness	3dB p-p max
Phase non-linearity	15 degrees typical
Output power at 1dB compression	>300W
Output port	
Impedance	50 Ohm nominal
Connector	N type (f)
VSWR	1.4:1 max
Output monitor	Uncalibrated diode detection at each power amplifier output
Environment	Indoor workshop or laboratory
Mechanical	
RA960 Drive amplifier	2U high 19" rack mounting
RA961 Power amplifier	3U high 19" rack mounting
D8106 Power combiner	
Mains Power Supply	
Voltage range	90 – 250 Volts
Power consumption	5 kWatt max under CW conditions
AC line connections	IEC 320 C14 chassis plugs.

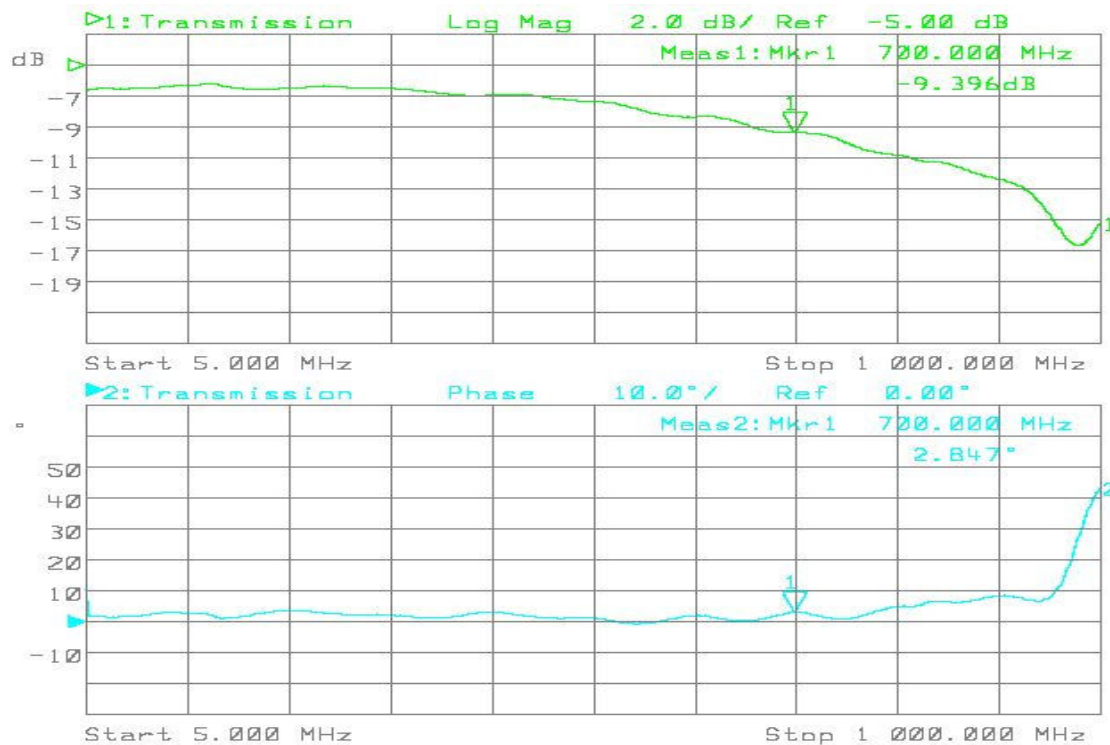
## Detailed proposal for the new 20-1000MHz prototype

We will target achieving the specifications below:

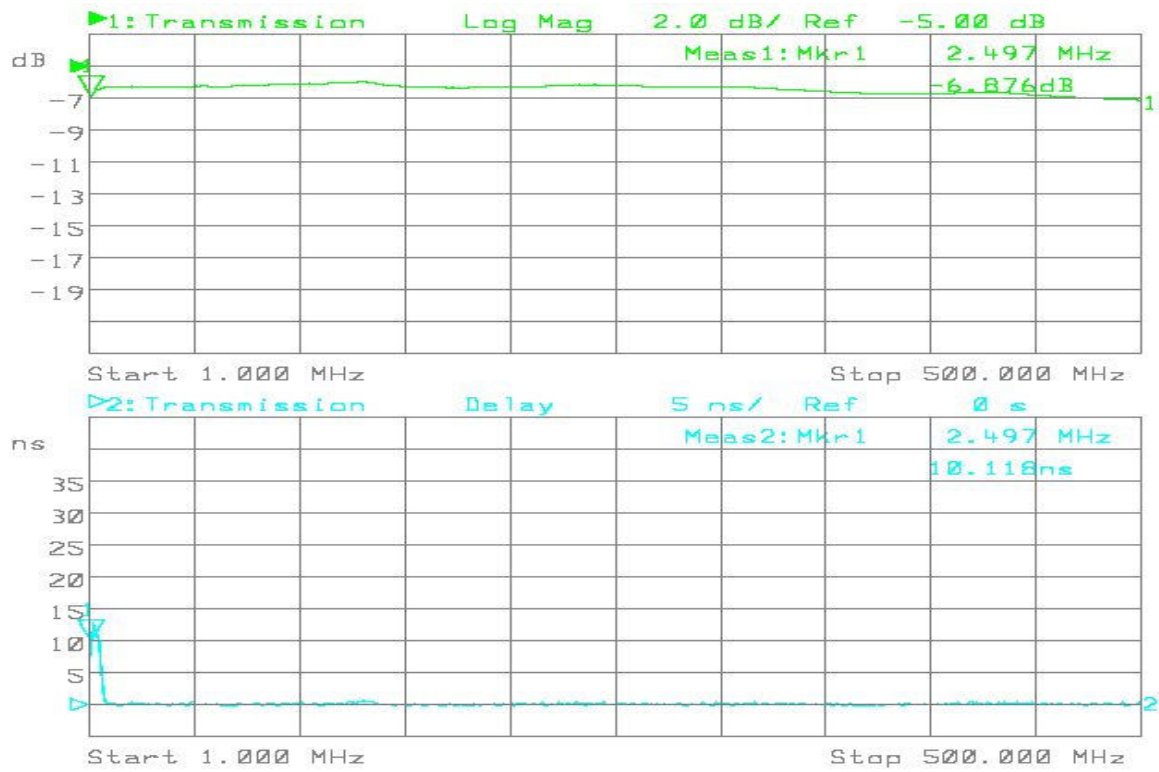
- 20-1000 MHz instantaneous bandwidth
- >20 dB gain, flat to +/- 1dB over the bandwidth and all power levels up to P1 dB
- Flat phase performance over the full band to within +/-10 Degrees
- Pure class A mode of operation, straight line constant gain with full range of input powers up to the P1db point. No transistor bias gating.
- PCB on heat sink type of construction, neat and transportable with metal cover but not in a full enclosure.
- DC power supplies required at voltage and current TBD
- Input and output connectors: Type N
- DC connectors/ interfaces: solder pins
- Targeting 20-25 watt P 1dB output power

We plan to use the latest, small sized GaN transistors available and one has already been tested in a standard simple test fixture that shows promise for achieving the full results required, see below:

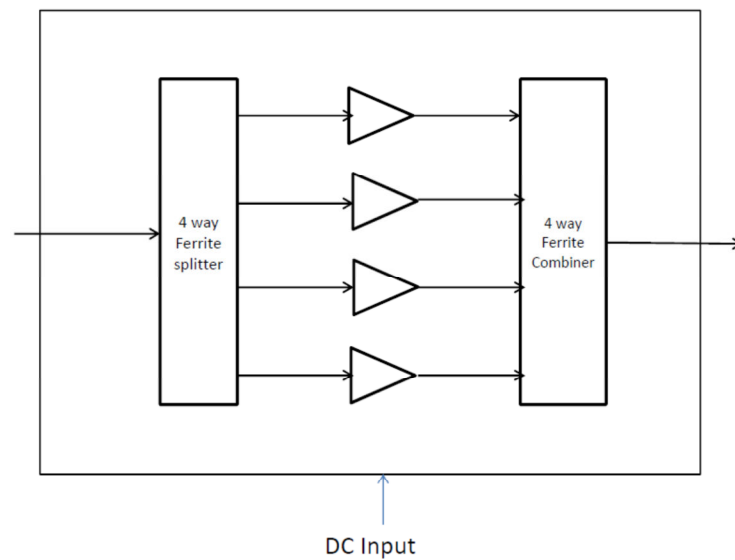
### Gain phase up to 1000 MHz (Single stage with 30 dB attenuator)



## Gain / Delay plot up to 500 MHz



## Block diagram of proposed prototype:



### **Commercial proposal**

Quantity 1, delivered prototype amplifier consisting of: 4 way splitter, 4 output stages and the output combiner, and test data. \$15,850 USD

### **Proposed Prototype Development and Delivery schedule**

Approx. 8-10 weeks is required to design and build one of these.

Indicative prices for full 250-300 watt systems consisting of 4 rack-mounted main stages, rack-mounted driver and output combiner:

Quantity	Price each
1	\$116,000
2	\$103,500

The above prices are FOB InterTronic Solutions

**This quotation is valid for 60 days from the date on this document**

**Purchase orders to be made out to InterTronic Solutions Inc.**



Peter Shield  
InterTronic Solutions Inc